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# Pediatric Solid Pseudopapillary Tumor of the Pancreas: Case Series and Literature Review

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## Abstract

We describe a case series of children with solid pseudopapillary tumor of the pancreas and present a literature review from a pediatric perspective. The tumor occurs overwhelmingly in young women, is rare, often large and has a low-grade malignant potential. Most patients present with non-specific abdominal symptoms, although occasionally it may be discovered incidentally in asymptomatic individuals. The diagnosis is based on characteristic findings seen in imaging modalities and confirmatory histopathology and immunohistochemical profiles. Treatment is surgical and the operative approach can include enucleation, segmental pancreatectomy or Whipple procedure, depending on the tumor's pancreatic anatomic location. Overall, with complete resection, the neoplasm is associated with an excellent prognosis, with outcomes more favorable in children than in adults.

**Keywords:** Pancreatic tumor, Children, Abdominal pain, Cytology, Pancreatectomy

## 1 Introduction

Solid pseudopapillary tumor of the pancreas (SPT) occurs uncommonly in the pediatric population. The neoplasm, known as Frantz's tumor, is named after the American pathologist, Virginia Kneeland Frantz, who first accurately described the tumor in a clinicopathologic series and extensive autopsy review in 195[1]. Affected individuals often exhibit nonspecific abdominal symptoms such as nausea, vomiting and/or abdominal pain. Typically, the neoplasm presents as a solitary mass with low malignant potential and occurs in young females in their third decade of life. As such, a considerable extent of the SPT literature is centered around adults. Herein, we summarize a case series of children diagnosed with SPT and provide a literature review relevant to the pediatric population.

## 2 Case Series

Chart data was obtained from the medical records of four pediatric patients with biopsy-proven SPT. Information collected included age, gender, clinical signs/symptoms at presentation, complete blood cell count, comprehensive

**Table 1: Comparison and summary of presentation, findings, management, and follow-up of the cases**

| | Case 1 | Case 2 | Case 3 | Case 4 |
|---|---|---|---|---|
| Age at presentation | 17 years | 12 years | 16 years | 15 years |
| Gender | Female | Male | Female | Male |
| Presenting symptoms | Acute upper abdominal pain, nausea, emesis | Incidental finding during pneumonia investigation | Epigastric pain, nausea, bloating, decreased appetite x 1.5 months | Right upper quadrant pain |
| Abnormal labs | Mild leukocytosis (WBC = 16.8 k/mm$^3$) | Elevated serum amylase (146 U/L) | None | None |
| Serum Tumor Markers – Normal | AFP, CA 19-9, VMA and HVA | AFP, CA-125, betahCG | CA 19-9 | AFP, CA 19-9, CA 125 |
| Pancreatic location and size of mass | Body and tail | Head | Head, neck and body (by direct visualization in operating room) CT: 5.4 x 5.1 cm | Tail |
| | MRI: 14.9 x 12 cm | MRI: 4.2 x 2.8 cm | | MRI: 8.5 x 8.2 cm |
| Immuno-Profile | | (FNA Specimen) | | |
| Beta-catenin | + | + | + | + |
| Synaptophysin | + | + | + | TNP |
| Alpha-1-Antitrypsin | + | + | TNP | TNP |
| CD10 | + | + | TNP | + |
| Vimentin | TNP | TNP | TNP | + |
| Progesterone Receptor | TNP | + | TNP | + |
| Chromogranin A | + | - | - | TNP |
| Treatment | Spleen-preserving distal pancreatectomy, negative resection margins | Awaiting surgery | Whipple procedure, negative resection margins | Spleen-preserving distal pancreatectomy, negative resection margins |
| Post-operative patient status | Clinically well, 2 years post-op | Not Applicable | Pancreatic insufficiency, no tumor recurrence 5 years post-op | Clinically well, 2 years post-op |

**Abbreviations:** alpha-fetoprotein (AFP), carbohydrate antigen 19-9 (CA 19-9), cancer antigen-125 (CA-125), random urine vanillylmandelic acid (VMA), random urine homovanillic acid (HVA), test not performed (TNP)

metabolic panel, uric acid, lactate dehydrogenase (LDH), serum amylase, lipase, serum alpha-fetoprotein (AFP), carbohydrate antigen 19-9 (CA 19-9), cancer antigen-125 (CA-125), random urine vanillylmandelic acid (VMA), random urine homovanillic acid (HVA), radiologic studies, operative reports, pathology, management, and outcomes. Their ages ranged between 12- and 17-years-old (mean 15 years). Two patients were males. Presenting symptoms ranged from asymptomatic to acute-onset and up to 1.5 months duration described as upper, epigastric, and right upper quadrant abdominal pain, nausea, emesis, bloating, and anorexia. All laboratory tests were within the normal range except one patient had transient mildly elevated total white blood cell count (16.8 k/mm$^3$) and one had mildly elevated serum amylase levels (146 U/L). Serum tumor markers, when performed, were within normal limits. The tumor was confirmed to originate in the pancreas by computerized tomography (CT) and/or magnetic resonance imaging (MRI) and occurred in the following anatomic areas: (1) body and tail, (2) head, (3) head, neck and body, and (4) tail (Fig. 1 A-D). Tumor size at the largest diameter ranged from 4.2 to 14.9 centimeters (mean 8.25 centimeters). Distal metastases were not seen. Surgical intervention was carried out from one to eight weeks from the time of diagnosis. A total mass resection

with negative margins was performed in three patients; two patients had a spleen-preserving distal pancreatectomy, one patient underwent a Whipple procedure, and one patient is awaiting surgery. The post-operative patients are clinically well; however, the Whipple procedure patient requires pancreatic supplementation for exocrine pancreatic insufficiency. Pertinent details of the cases are outlined in Table. 1.

## 3 Discussion

Pancreatic neoplasms in the United States represent 3.2% of all new cancer cases and have an annual incidence of 13.7 per 100,000[2]. They are extraordinarily rare in the under 19-year age group with an estimated incidence of 0.0424 newly diagnosed cases reported per 100,000 people in the United States[3]. Overall, SPT comprises approximately 0.9%–2.7% of all exocrine tumors[4]. In children, the Surveillance, Epidemiology, and End Results (SEER) database study, using the WHO diagnosis guideline classification, recently recognized SPT as the most common pancreatic malignancy subtype (48%) followed by neuroendocrine tumors (25.7%) and pancreatoblastoma (10%)[3].

In one review of 718 patients including both children and adults, SPT was most frequently found in young women in the third decade with a mean age of 21.9 years and a female-to male ratio of approximately 10:1[5]. In a 20-year pediatric series of patients ages 9-17 years, the tumor occurred at a median age of 14 years and had a significantly lower female-to-male ratio of only 1.75:1[6] Similarly, half of the children in our series (despite the small sample size) were also male highlighting the finding that unlike adults, the tumor is not nearly exclusive to females in pediatric populations.

SPT is categorized histologically as an epithelial pancreatic tumor. It is speculated that during early embryogenesis, the genital ridge and the pancreas anlage are in close physical proximity and SPTs are derived from genital ridge-related cells that were incorporated into the pancreas during organogenesis[7]. SPT has not been associated with any genetic syndrome. However, pathogenic point mutations in the CTNNB1 gene are found in 93% of cases[8]. The CTNNB1 gene is located on chromosome 3p and encodes beta-catenin protein which is essential for cell signaling and maintaining epithelial cell layers. Interestingly, mutations in K-ras oncogene, DPC4 and p53 tumor suppressor genes, which are common in pancreatic ductal adenocarcinoma, are seen rarely in SPT, suggesting that SPT has a unique genetic evolutionary pathway[9].

Several studies have demonstrated that the tumor appears as a solid and/or cystic mass that can develop in any part of the pancreas. One large study with 22% of cases reported in children showed a predilection for the tail (35.9%) and the head (34%); then, in decreasing frequencies, the body (14.8%), the body and tail (10.3%), the head and body (3.05%), the neck (1.01%), and the uncinate process of the pancreas (0.43%)[5]. Another 15-year retrospective study of 22 patients showed these tumors presented at the pancreatic tail (54.5%), body (41%), and head (4.5%) with all 3 pediatric patients having tumor location in the tail[10]. Remarkably, albeit small, our series exhibited that SPT may involve overlapping anatomic parts of the pancreas involving two or more areas such as the body and tail, and also the head, neck and body.

In a 15-year pediatric study, Choi and colleagues[11] reported initial presenting signs and symptoms of upper abdominal pain (87%), palpable abdominal mass (35%), dyspepsia (26%), serum amylase elevation (18%) and/or a history of abdominal trauma (17%). Patients are asymptomatic in around 2% of cases and can be identified during imaging for unrelated reasons--as demonstrated in case 2 of this series. Our cases also reported vague symptoms which included appetite loss, nausea and vomiting which are more common in children than adults.

Both CT and MRI are the most often used radiographic modalities in diagnosis. SPT is usually seen as a well-demarcated solitary mass with varying amounts of solid and cystic areas surrounded by a fibrous capsule (Fig. 1 A-D.) In children, MRI is the preferred imaging modality because children are more susceptible to the long-term and cumulative effects of ionizing radiation; and, importantly, MRI provides higher soft tissue resolution precisely distinguishing between solid and cystic components of complex tumors which are characteristic of SPT[12]. In a systematic literature review of 2744 adults and children diagnosed with SPT, the mean tumor size was 8.6 cm[13]. A Korean retrospective analysis surprisingly showed the mean tumor size in children significantly larger than in adults (8.0 vs 6.0 cm)[14]. In addition, they showed that pre-operative data such as age, sex, tumor size, tumor location, and elevated carcinoembryonic antigen and elevated carbohydrate antigen 19-9 were not predictive of malignant potential.

In a world literature review of 289 SPT cases[15], malignancy was seen in 14.7% of patients. Furthermore, among patients with malignant tumors, 55% exhibited metastases: 50% had liver involvement and/or peritoneal dissemination, 5% had lymph node metastases, and 45% showed direct invasion into adjacent structures such as organs, vessels, spleen, stomach, or duodenum. In one analysis, Horisawa and colleagues[16] reviewed 174 cases of SPT, which included 52% of patients under 20 years of age. They found metastasis and/or local recurrence in 12.6% of cases, with these events occurring at a mean age of 29.4 years. Notably, 41% of those with metastases

or local recurrence were present at diagnosis, although only one of the six pediatric cases exhibited such findings at initial presentation.

The differential diagnosis of pediatric SPT includes primary pancreatic neoplasms such as pancreatoblastoma, acinar cell carcinoma, and pancreatic neuroendocrine tumors, each distinguishable by their characteristic histological features, immunohistochemical profiles, and serum tumor markers such as elevated alpha-fetoprotein levels[17]. In children, metastatic tumors to the pancreas are rare, however, they are most often associated with rhabdomyosarcoma, Ewing sarcoma, osteosarcoma, and neuroblastoma[18].

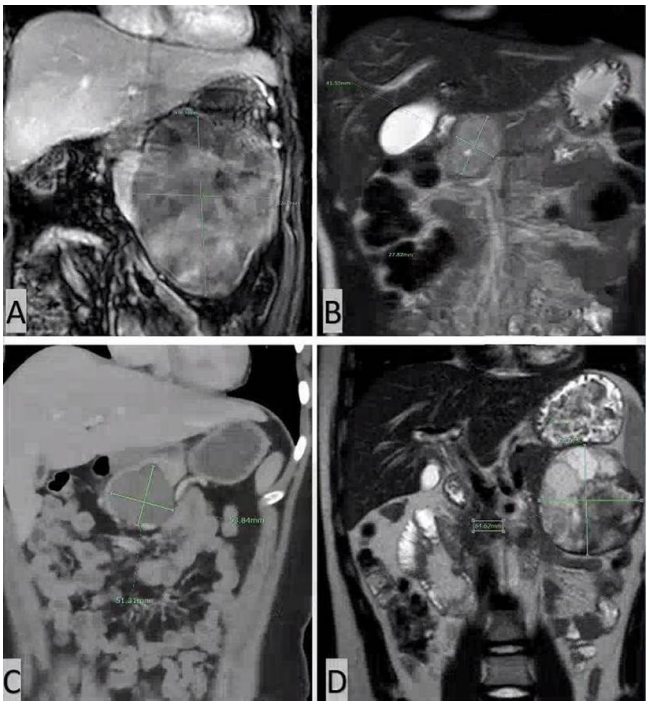


**Fig. 1: A- T1-weighted coronal image of MRI abdomen with contrast from Case 1 demonstrating a welldemarcated solid, heterogeneously enhancing mass in the body and tail of the pancreas measuring 14.9 x 12 cm; B- T2-weighted coronal image of MRI abdomen from Case 2 demonstrating a well-circumscribed mass lesion in the head of the pancreas measuring 4.2 x 2.8 cm; C- Coronal contrast enhanced CT image from Case 3 demonstrating a hypoattenuating lesion with relatively decreased enhancement at the pancreatic neck and body measuring 5.4 x 5.1 cm; D- T2-weighted coronal MRI image from Case 4 demonstrating a heterogenous, solid, well-circumscribed lesion in the pancreatic tail measuring 8.5 x 8.2 cm**

The macroscopic appearance of the tumor is described in Fig. 2. Microscopically, features of SPT include a mix of solid and pseudopapillary areas. Solid regions consist of uniform tumor cells with capillary-sized blood vessels, while pseudo papillae form due to cellular detachment, creating fibrovascular stalks or rosette-like structures (Fig. 3, panels A-B). The stroma often shows hyalinization,

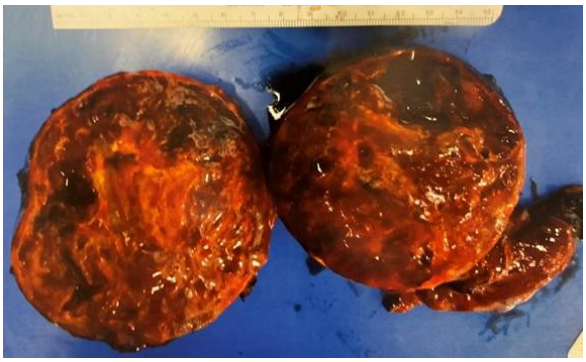

**Fig. 2: Gross appearance of the resected mass from Case 4, demonstrating a well-defined lesion arising from the pancreatic tail. The mass measured 10.0 × 8.0 × 6.0 cm and weighed 405.1 g. A fibrous capsule is evident, along with prominent areas of hemorrhage, necrosis, and cystic change**

hemorrhage, foamy macrophages, calcifications, and cholesterol clefts. Tumor cells have moderate eosinophilic cytoplasm, intracytoplasmic PAS+ diastase-resistant hyaline globules, and perinuclear vacuoles. Nuclei are uniform with fine chromatin, inconspicuous nucleoli, and characteristic grooves, with rare mitotic figures[19]. Immunohistochemically, SPT demonstrates aberrant nuclear staining for beta-catenin (98%), along with positivity for alpha-1-antitrypsin (95%), vimentin (88%), CD10 (63%) and synaptophysin (55%). In addition, androgen (81%) and progesterone (63%) receptors are frequently expressed. In contrast, chromogranin A (9%) and estrogen receptor are usually negative, helping to distinguish SPT from pancreatic neuroendocrine tumors (Fig. 3, panels C-H). In a Chinese study[20], nuclear translocation and accumulation of beta-catenin protein were seen in all SPT cases whereas pancreatic endocrine tumors showed solely membranous and cytoplasmic labeling and were negative for nuclear accumulation.

A complete surgical resection is the recommended treatment with a greater than 95% cure rate[21]. Unfortunately, the median survival rate decreased to only 5.7 years when the mass was incompletely resected either micro or macroscopically[22]. A cancer database study[23] comparing survival rates between children and adults showed that children had a significantly higher survival rate—97.5% versus 87.3%, respectively. Curiously, this survival difference remained unexplained even after controlling for gender, ethnicity, race, comorbidities, tumor stage, extent of resection and use of adjuvant therapies implying that there are significant differences in SPT pathophysiology between children and adults.

SPT in the pancreatic body or tail is usually treated with distal pancreatectomy while those involving the pancreatic head require a Whipple's procedure or pylorus-preserving pancreatoduodenectomy[24]. Tumor enucleation may be appropriate in small well-circumscribed tumors without local vessel invasion. A laparoscopic approach can also be considered depending on tumor size less than 4.7 cm, mass size/abdominal diameter ratio less than 0.3, and the degree of portal vein or superior mesenteric vein compression grade 2 or lower[25], although there is no expert consensus on the safety and feasibility of minimally invasive procedures in pediatrics. Reported 30-day post-operative complications include pancreatic fistula formation (17%), chyle leak (6%), delayed gastric emptying (4%), intra-abdominal collections (4%), and post-pancreatectomy hemorrhage (2%)[26]. Other less common complications described include pancreatitis, steatorrhea, wound infection, biliary fistula, prolonged gastric emptying, gastrointestinal bleeding, diabetes mellitus, and ileus[27]. Liver transplantation can be considered in select cases. Reddy *et al.*[28] outlined six published case reports of patients, including a 14-year-old female,[29] with unresectable SPT liver metastases and no extrahepatic disease. All underwent successful liver transplantation. In one literature review of 523 young patients with SPT, mostly in the pediatric age group, only 3.8% received adjuvant chemotherapy, radiation or additional surgical intervention[30]. While none of the cases in our cohort demonstrated metastases, early involvement of the oncology team is recommended to assess the potential need for neo/adjuvant therapy.

Currently, there are no established guidelines for surveillance after surgery; however, long-term monitoring is important. In a literature review of patients with SPT, Abudalou and colleagues[31] proposed that post-surgical follow-up include obtaining a CT scan 6 months post-operatively to check for tumor resolution or recurrence, and thereafter yearly, for at least 5 years or longer, depending on the suspicion for malignant potential, such as tumor size greater than 5 cm, adjacent structure invasion, histologic atypia, or metastases. Of the three patients who underwent surgical resection in our young group, two had repeat CT imaging within 2 years of the procedure with no recurrence. The other patient had serial imaging for 5 years post-procedure and remained tumor-free.

## 4 Summary

These cases and literature review highlight the importance of recognizing solid pseudopapillary tumor of the pancreas in the pediatric population. While SPT is a rare tumor, it has recently been identified as the most common pancreatic malignancy subtype in children by the Surveillance, Epidemiology, and End Results database study.

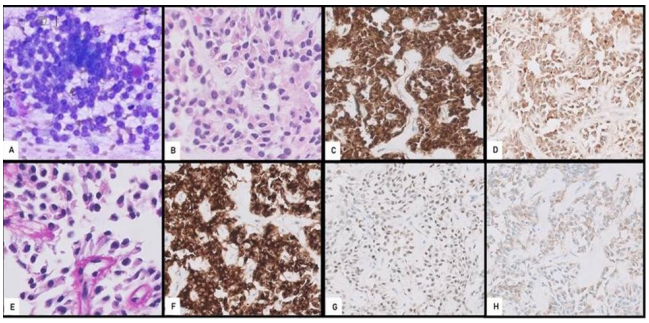

**Fig. 3: Cytologic and immunohistochemical features of SPN. A from Case 3, B-H from Case 2. A- Fine-needle aspiration (FNA) smear from Case 3 (400×, Diff-Quik stain) shows a highly cellular specimen with loosely dispersed, relatively bland and uniform cells containing intracytoplasmic hyaline globules. B- Cell block from Case 2 (400×, hematoxylin and eosin stain) demonstrates intermediate cellularity with loosely arranged cells exhibiting moderate amounts of cytoplasm and eosinophilic hyaline globules, some arranged in delicate papillary fronds. The nuclei are round to oval with nuclear grooves and finely granular chromatin. C-β-catenin shows aberrant nuclear positivity (200×); D- alpha-1-antitrypsin positivity (200×); E- PAS stain highlights hyaline globules (400×); F- CD10 shows cytoplasmic positivity (200×); G- progesterone receptor positivity (200×); H- synaptophysin is positive (200×), whereas chromogranin A (not shown) is distinctly negative**

The neoplasm is typically seen in young adult women in their third decade of life. However, in pediatric populations, although females are more commonly affected, it is important to recognize that males demonstrate a significant proportional incidence, which may aid in timely diagnosis. In addition, abdominal symptoms in children are often more nonspecific. It carries an excellent prognosis following complete resection and a low rate of recurrence or metastasis, but outcomes are significantly more favorable in children than in adults. Further research is needed to identify molecular biomarkers that can predict malignant potential and help guide therapeutic decisions, ultimately improving treatment results in both children and adult populations.

## 5 Disclosures

Institutional Review Board approval #23118 was obtained from New York Medical College and The Clinical Research Center at Westchester Medical Center.

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